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SOME CHARACTERISTICS OF MICROWAVE TYPE IV RADIO BURSTS AND THE ACCELERATION OF SOLAR COSMIC RAYS

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SOME CHARACTERISTICS OF MICROWAVE TYPE IV RADIO BURSTS AND THE ACCELERATION OF SOLAR COSMIC RAYS

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Solar cosmic rays are, in general, produced from solar flares which accompany type IV radio bursts of wide frequency range. Kundu and Haddock (1960) showed that the emission of the microwave component of the bursts is necessary for the generation of solar cosmic rays. Since this microwave emission begins with the start of the explosive phase, high energy electrons (10^2 - 10^4 Kev) responsible for this emission seem to be accelerated during this phase (e.g., Svestka, 1970; Sakurai, 1971).

It is, therefore, certain that those electrons are accelerated simultaneously with solar cosmic ray protons and heavier nuclei. It seems thus that the efficiency of the electron acceleration is closely related to that of the proton's. Solar cosmic ray protons and heavier nuclei are exclusively accelerated by the Fermi mechanism in the initial stage of acceleration (i.e., in the explosive phase) (e.g., Hayakawa et al., 1964; Sakurai, 1965a; Wentzel, 1965). Furthermore, it is certain that the electrons under consideration are also accelerated by the same mechanism (Sakurai, 1971).

Since all particles are accelerated simultaneously by the same mechanism, it seems probable that some characteristics of the microwave component of type IV radio bursts (IVμ) are useful as a measure of the efficiency of solar cosmic ray

acceleration. The reason that the microwave emission is picked up is based on the fact that this emission starts with the beginning of the explosive phase. As a measure as mentioned above, we may consider the rise time and the peak flux intensity of the microwave emission during the initial development of type IV bursts.

At present, solar cosmic ray events are classified into three distinct types as F, F* and S from the view point based on the riometer observation (e.g., Obayashi, 1964; Sakurai, 1965b). We will here consider the first two types (F and F*) since, in general, the parent flares for S-type cosmic ray events do not accompany the microwave emission (IVμ). Furthermore, S-type events are identified as delayed onset type events.

In this paper, the importance of solar cosmic ray events is defined by three classes as I, II and III on the basis of polar cap absorption degrees as observed by riometer and ionosonde (Jonah, Dodson-Prince and Hedeman, 1965; Obayashi, et al., 1967; Hakura, 1968). This importance, though indirectly, gives the magnitudes of the incident fluxes and energy range of solar cosmic rays observed at the earth's orbit (e.g., Parthasarathy et al., 1964; Adams et al., 1966; Juday et al., 1969; Smart et al., 1970). As suggested by

Sakurai (1965b), this importance seems to be related to the manner of the development of solar flares and associated phenomena. It is thus important to examine the relationship of this importance with some characteristics of type IV radio bursts. Since the microwave emission (IVμ) is important on the generation of solar cosmic rays, we will here consider the relation of the importance of solar cosmic ray events with both the rise time and peak flux intensity of type IVμ bursts. This relation seems to give some clue to investigate the acceleration process of solar cosmic rays.

By using the observational data on solar cosmic ray events and type IVμ radio bursts (Maeda et al., 1962; Jonah et al., 1965; Obayashi et al., 1967; Hakura, 1968; Solar Geophysical Data, 1964-1967), the above relation has been examined. The results are shown in Fig. 1. The relations with the rise time and peak flux intensity are shown in Figs. 1(a) and (b), respectively. The figure shows that the rise time of the microwave emission (IVμ) tends to decrease as the importance of solar cosmic ray events increases, while the peak flux intensity tends to increase with the importance.

On the whole, the result obtained above indicates the following relation:

$$\log (\text{Rise Time}) \propto - \log (\text{Peak Flux})$$

$$\propto - \text{Importance of Solar Cosmic Rays}$$

This relation shows that, as the rise time becomes shorter, the peak flux intensity of type IVμ bursts increases with increase of solar cosmic ray events. This result means that, as the development of type IVμ bursts becomes more rapid, the peak flux intensity of the bursts and the fluxes of solar cosmic rays incident on the earth tend to increase. The relation between the importance of solar cosmic ray events and the influx of cosmic ray particles over the polar cap region has been studied by Adams et al., (1966) and Juday et al. (1969).

Since the emission power of type IVμ bursts is mainly determined by the number and energy of accelerated electrons, the rise time of the bursts seems to be correlated to the rapidity of the acceleration of electrons in the explosive phase. Hence the rapid rise of the bursts means that the electrons responsible for the bursts are rapidly accelerated to high energy enough to emit the bursts. Furthermore, the number of accelerated electrons should be larger since the peak flux intensity of the bursts increases.

We thus conclude that the rapidity of electron acceleration is closely related to the acceleration process of protons and heavier nuclei during the explosive phase. In other words, the acceleration of solar cosmic rays is closely connected with that of electrons. When we consider that the acceleration of both protons and electrons is mainly due to the Fermi mechanism, it becomes certain that protons, electrons and heavier nuclei are simultaneously accelerated by the same mechanism during the explosive phase. Furthermore, the rapidity of electron acceleration is closely correlated to the efficiency of solar cosmic ray acceleration.

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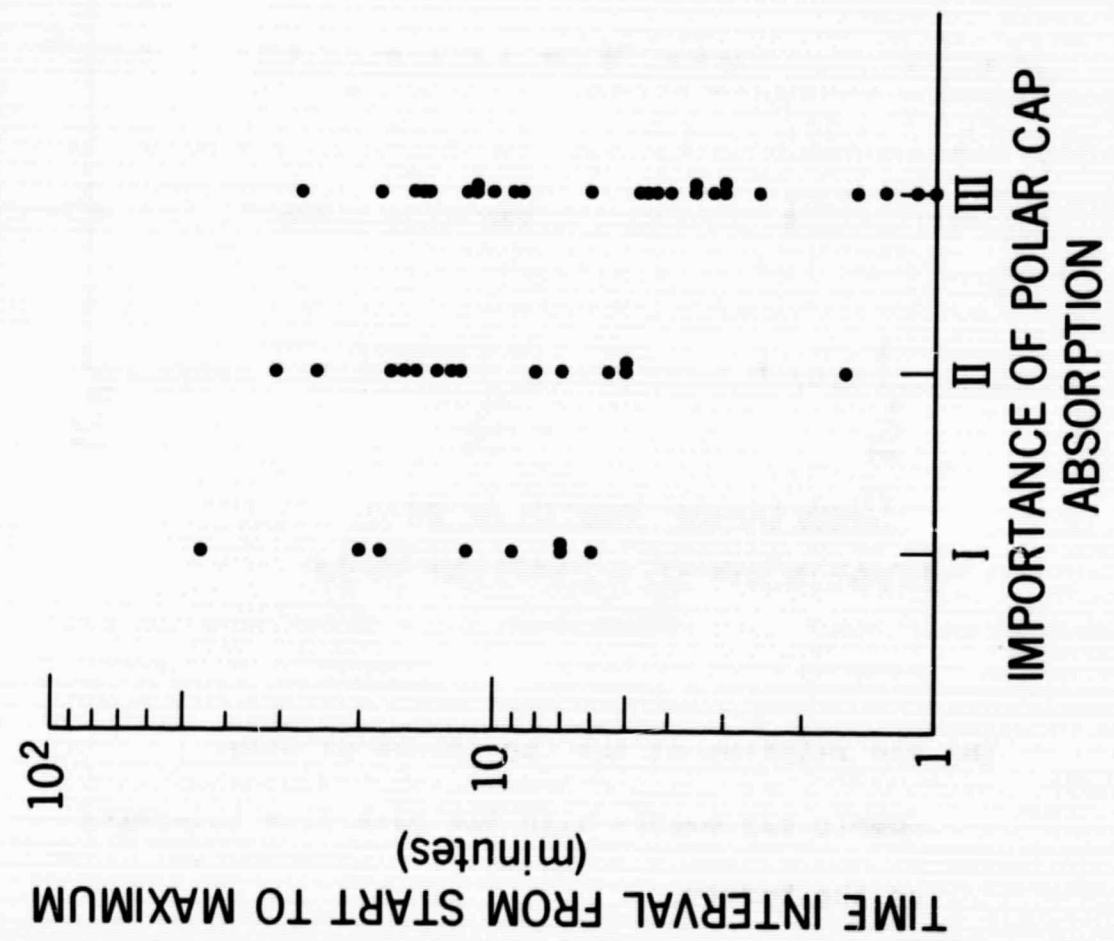
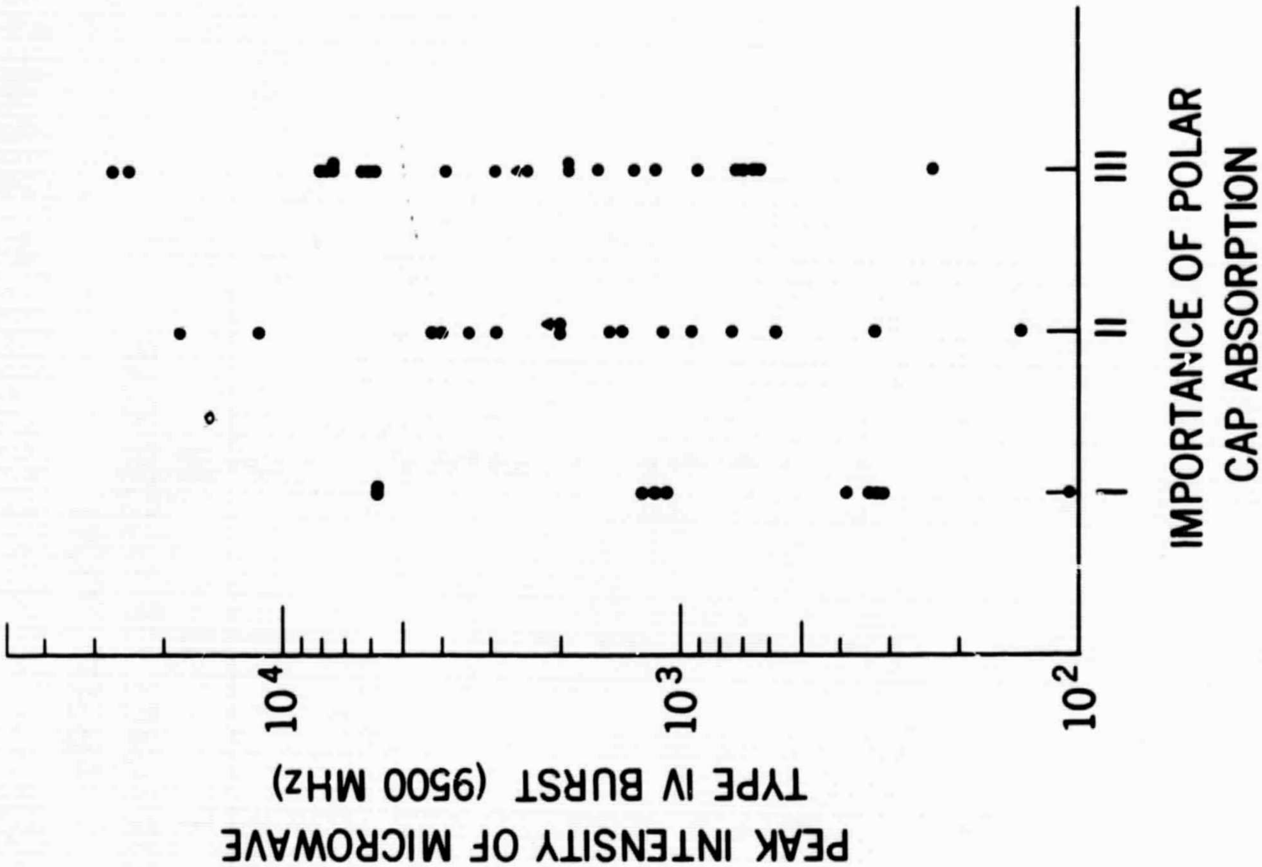


Fig. 1 - The relations between the importance of solar cosmic ray events and the rise time and peak flux intensity of type IVμ radio bursts at 9400 and 9500 MHz.

(a) The relation of the importance of solar cosmic ray events with the rise time of the bursts.



(b) The relation of the importance of solar cosmic ray events with the peak flux intensity of the bursts.